Study of Fuel Cell Water Transport With Neutron Imaging

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Relevance/Objective

4.4.3.2.4 Component Technical Barriers

(DOE R&D draft)

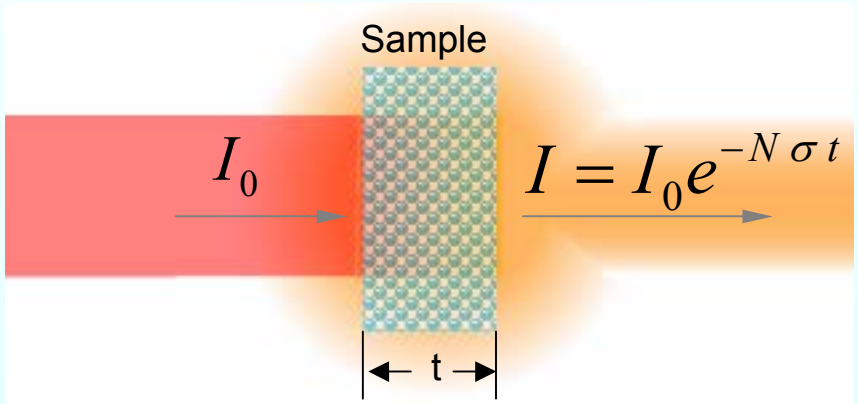
- **Thermal and Water Management**: …..Water management techniques to address humidification requirements and maintain water balance are required.

- **Component Durability:** MEA structural integrity and morphology.

Approach

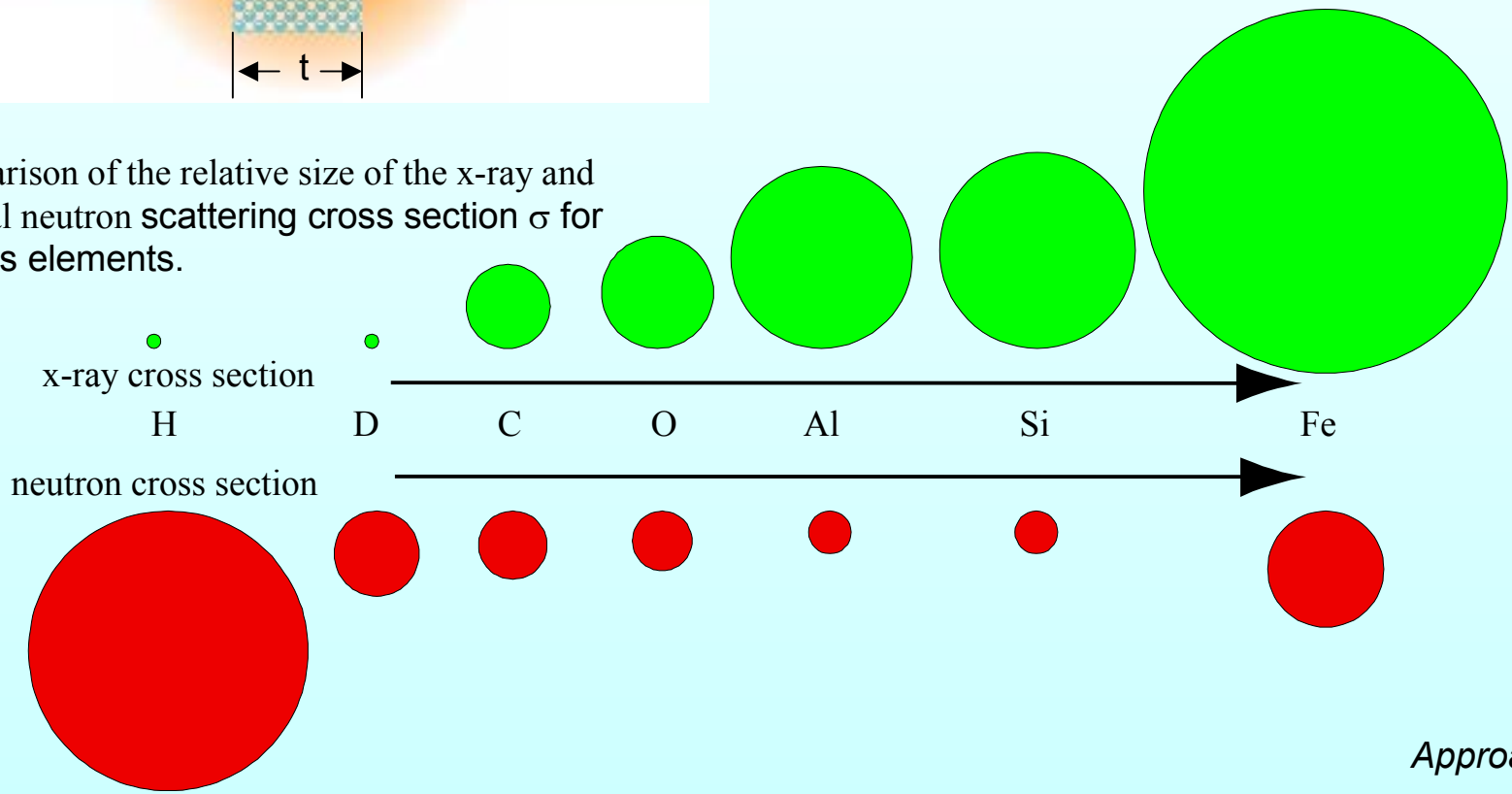
- Develop neutron imaging method to non-destructively visualize and quantify water transport in fully assembled operating fuel cells.
- Develop a nuclear reactor based state of the art ***neutron imaging user facility*** to study and characterize water transport for improving PEM fuel cell design, efficiency and reliability.
- Share research data with rest of the fuel cell community.
- Make scientific and technical development scalable to meet future needs.

Neutrons are perfect probes

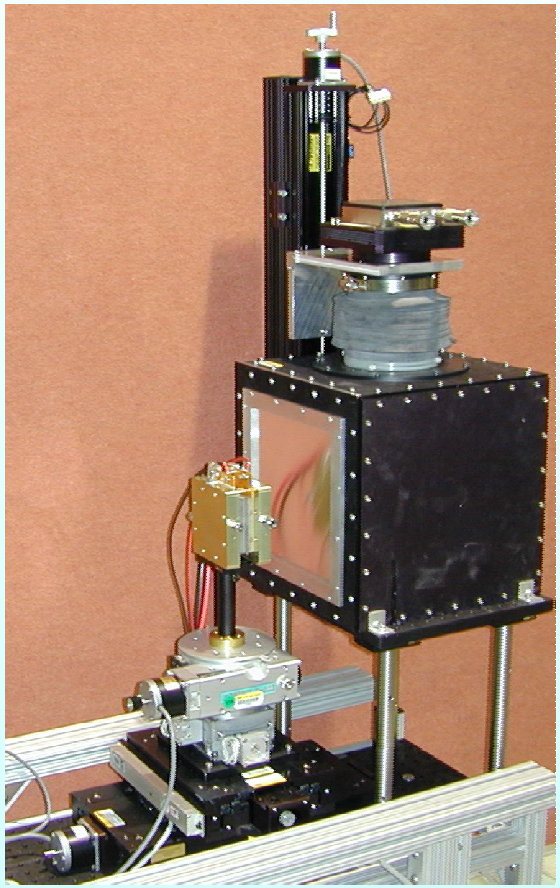


- N – numerical density of sample atoms per cm^3
- I_0 - incident neutrons per second per cm^2
- σ - neutron cross section in ~ 10^{-24} cm^2
- t - sample thickness

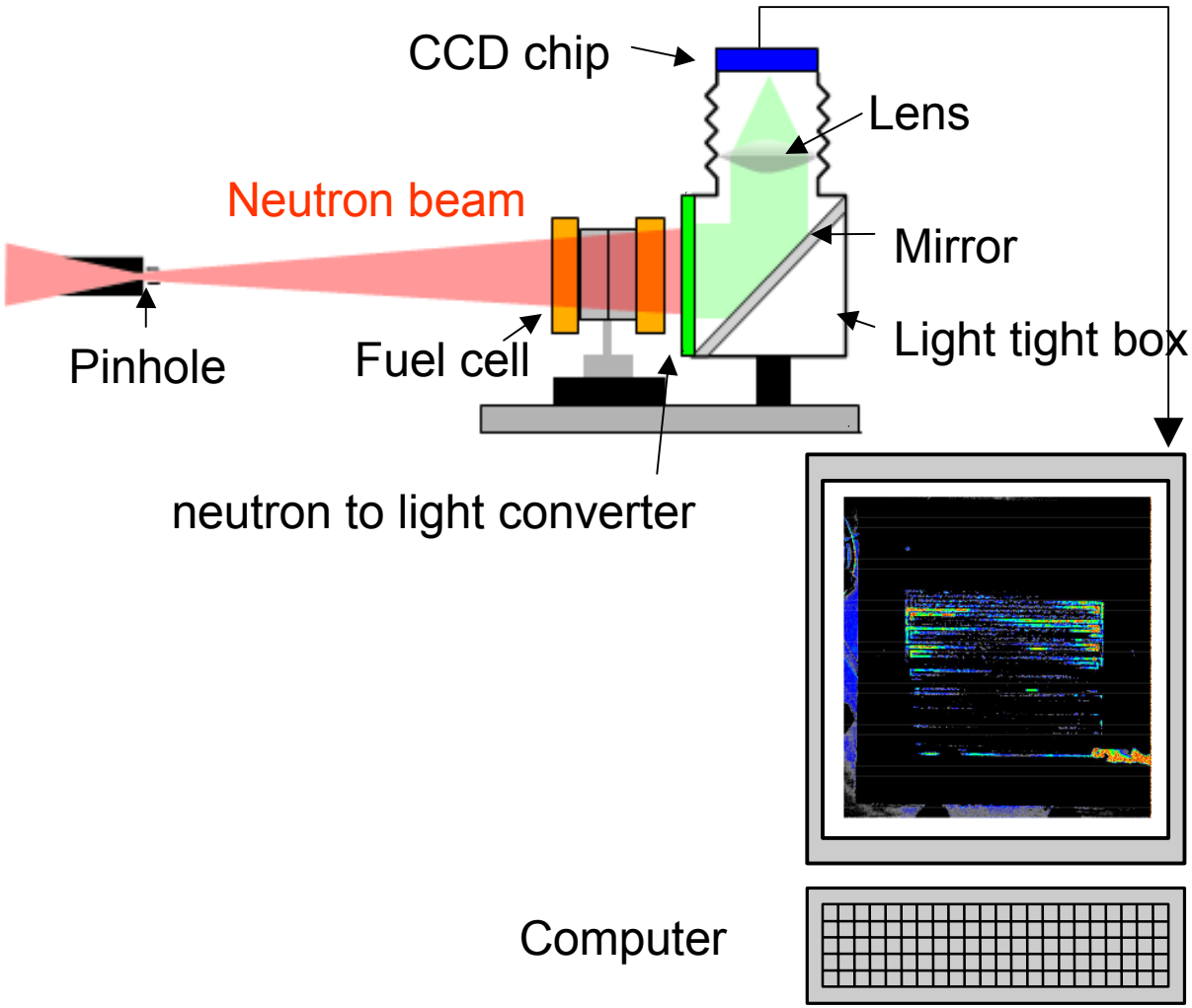
Comparison of the relative size of the x-ray and thermal neutron scattering cross section σ for various elements.



Neutron Imaging Setup



Picture of the detector and sample holder assembly



Project Timeline

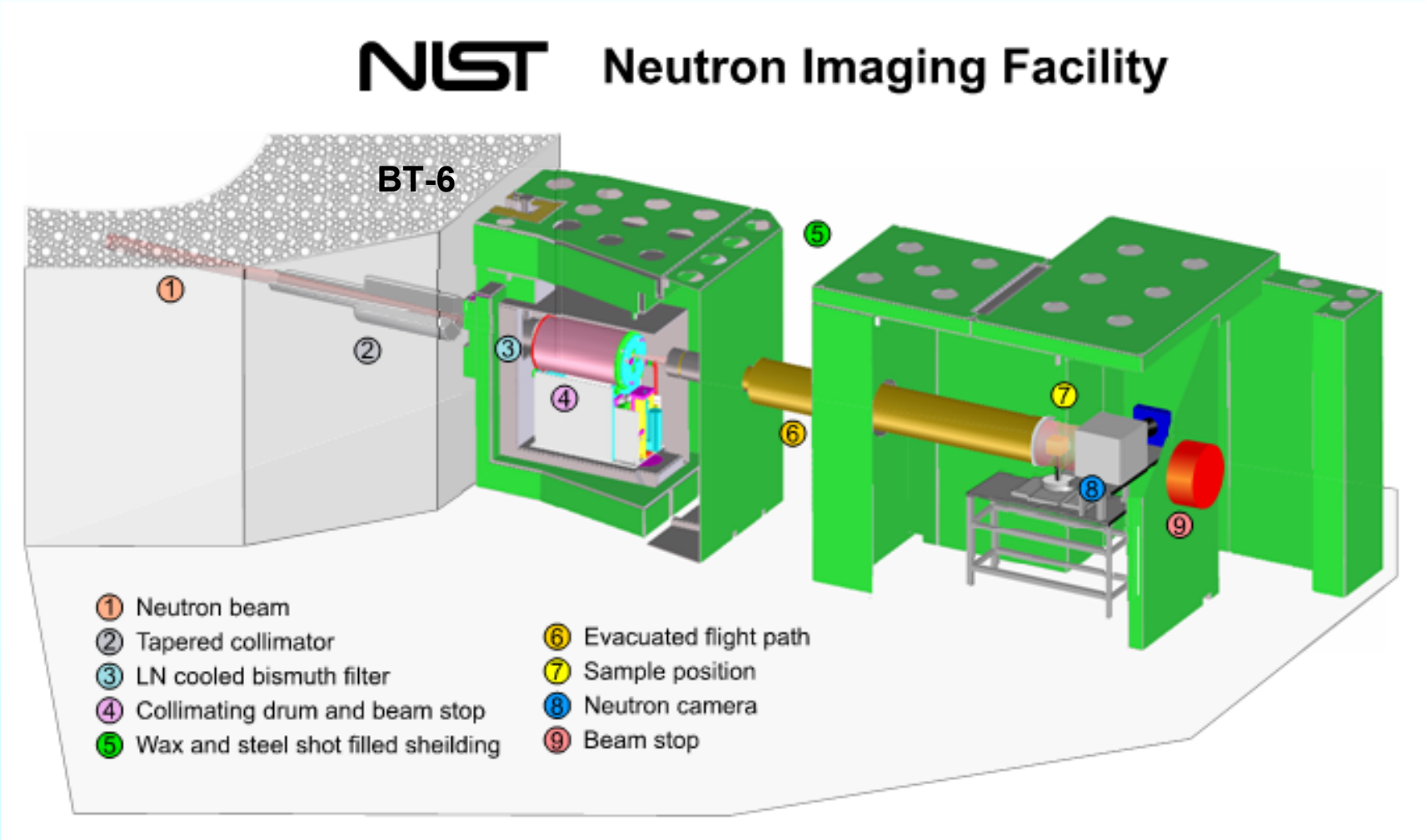
June 2000	Decision of DOE funding.
Sept.-Oct. 2000	**First demonstration of neutron imaging for real time visualization of water movement.**
Aug -Dec 2001	**Procure beam-line for facility development.**
	Design neutron optics for beam-line and decide on design.
	Initial test of *small* multi-stack fuel cells.
Jan. - Sept 2002	Construct Neutron Imaging Facility at BT-6 beam line at NIST reactor.
December 2002	**Industrial partners start using the facility on case by case temporary approval.**
March- April 2003	NIST reactor Safety Evaluation Committee approves routine operation of facility.
Present	**Scheduling and allocating beam time for internal and external users. Preparing results for publication.**

Accomplishment /Progress

Milestones
(2002-2003)

- Make the fuel cell imaging instrument fully operational by testing CCD detector system, constructing computer controlled fuel cell handling mechanism and optimizing data acquisition and analysis software. ***Completed***
- Study spatial and temporal distribution of hydrogen and water inside operating PEM fuel cells via neutron imaging and quantify hydrogen and water distribution. ***Completed and ongoing.***
- Share results with other fuel cell researchers in academic institutions and industry. Publish and present results in journals and conferences. ***Completed and in preparation (special care is needed to protect proprietary information)***

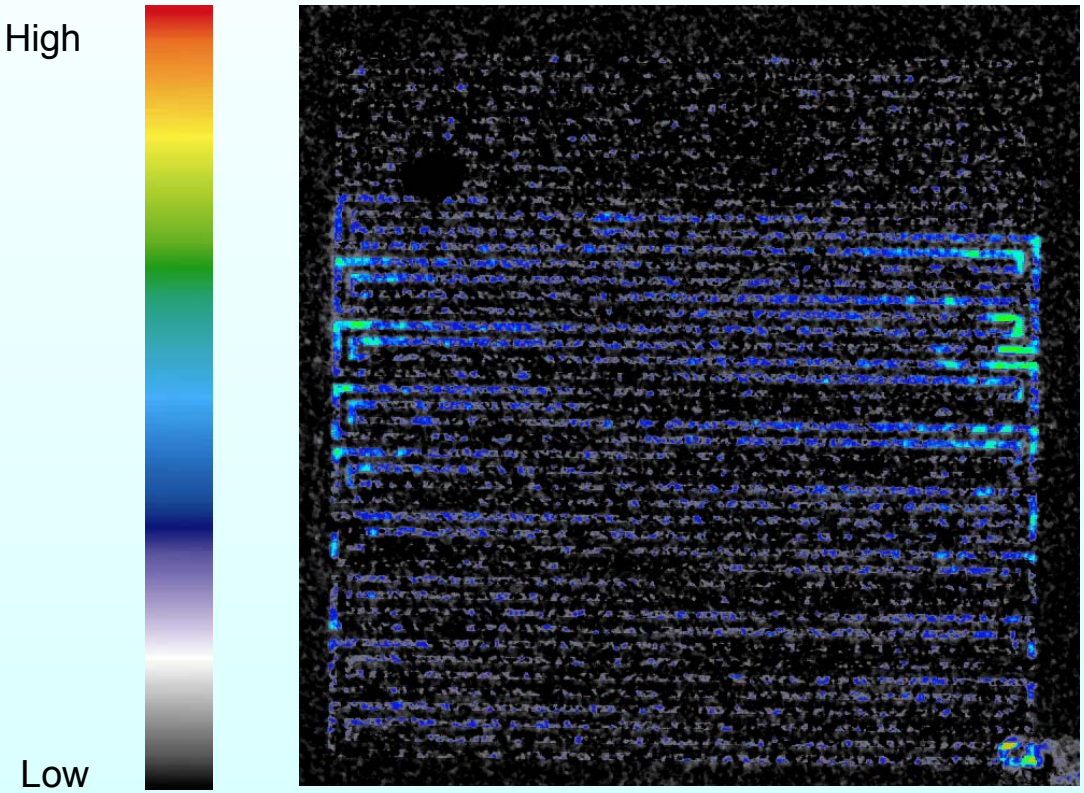
Dedicated Fuel Cell Test Station



- Intense neutron beam
- Single or multi-stack cell
- Variable beam diameter
- Variable resolution

Accomplishment

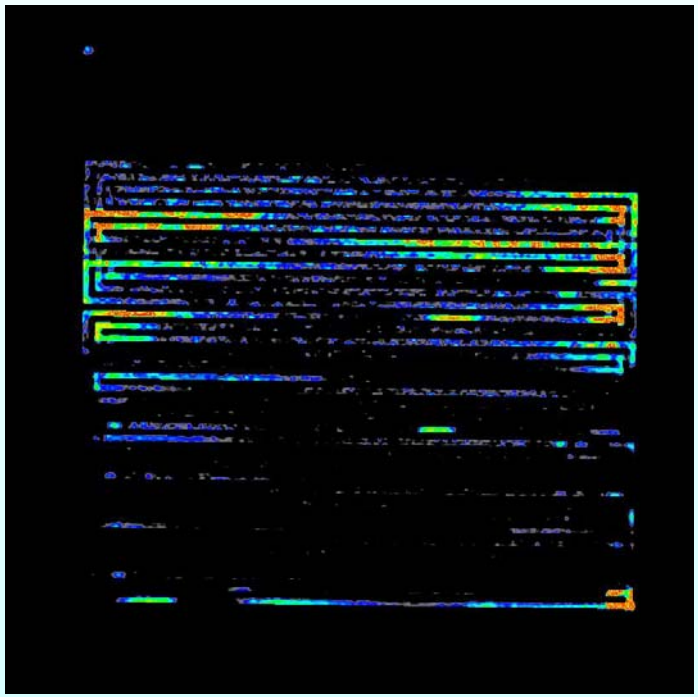
Water movement in fuel cells



Water sensitivity:
Better than 1 micro-gram in weight
30-50 micro-meter in thickness

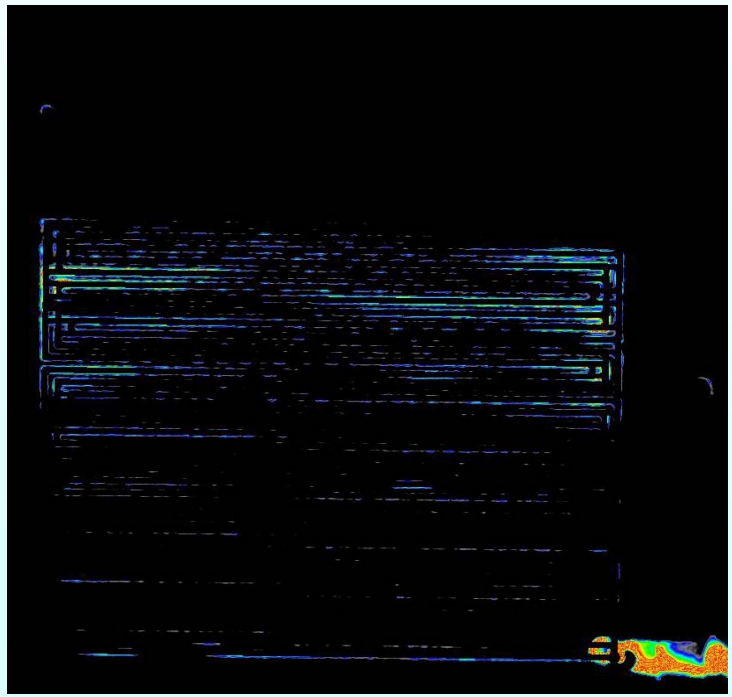
Accomplishment

Water inside fuel cell



High

Low

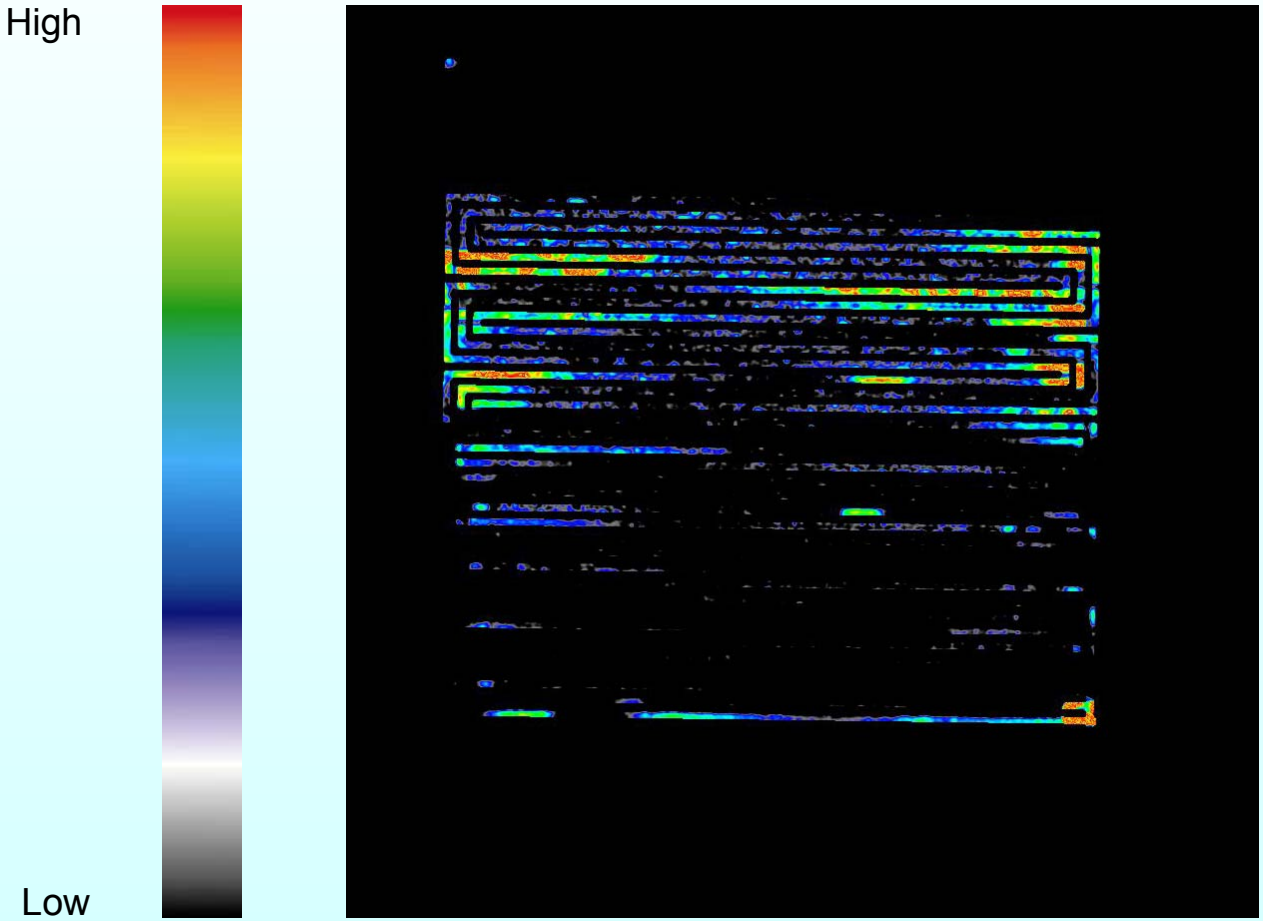


MEA + Cathode + Anode

MEA

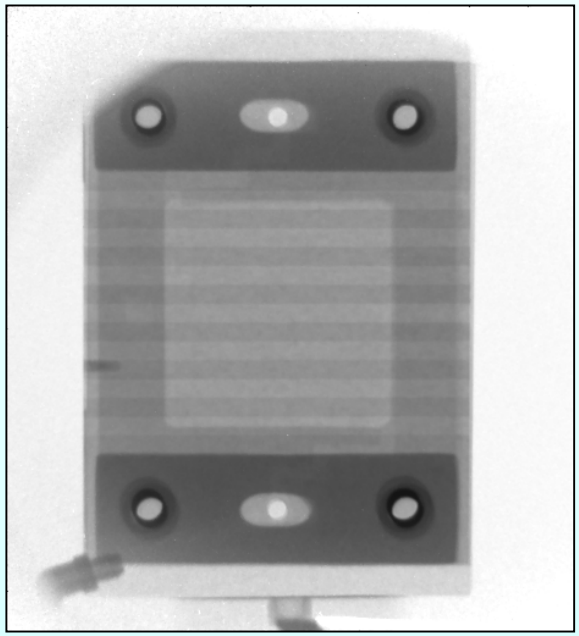
Accomplishment

Cathode Image

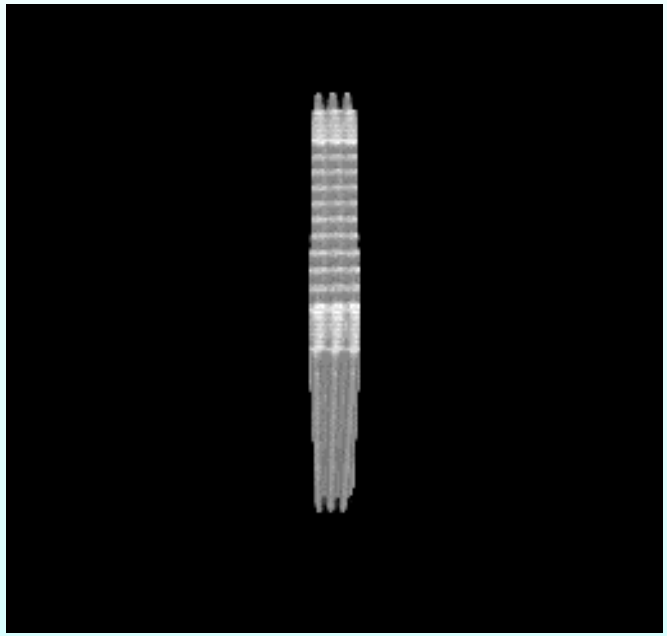


Anode Image ?

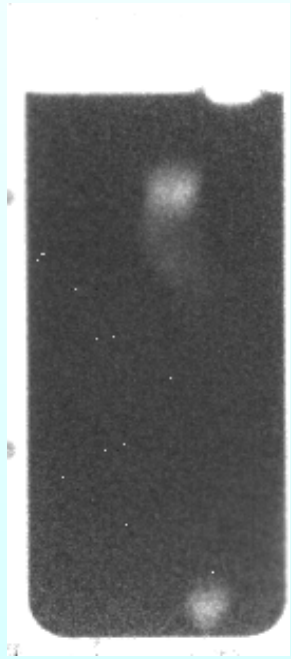
Extend measurements to 3-D



Single cell interior



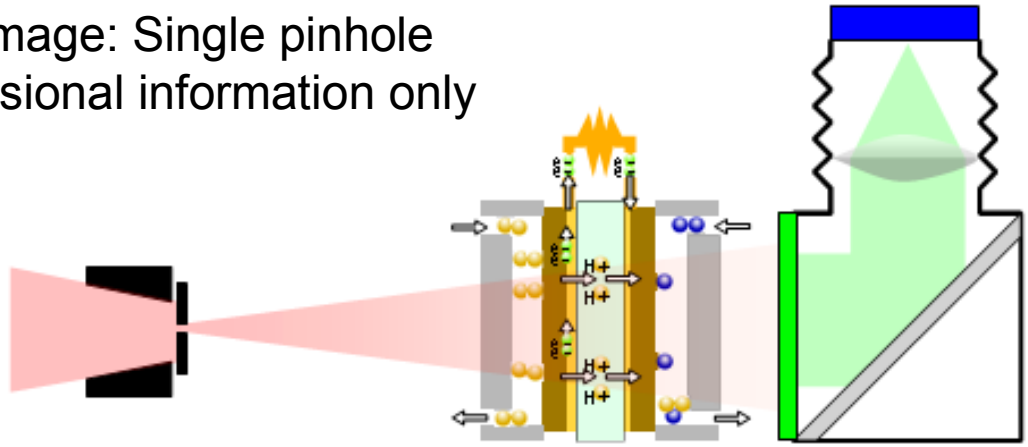
Multi-Cell outer layer



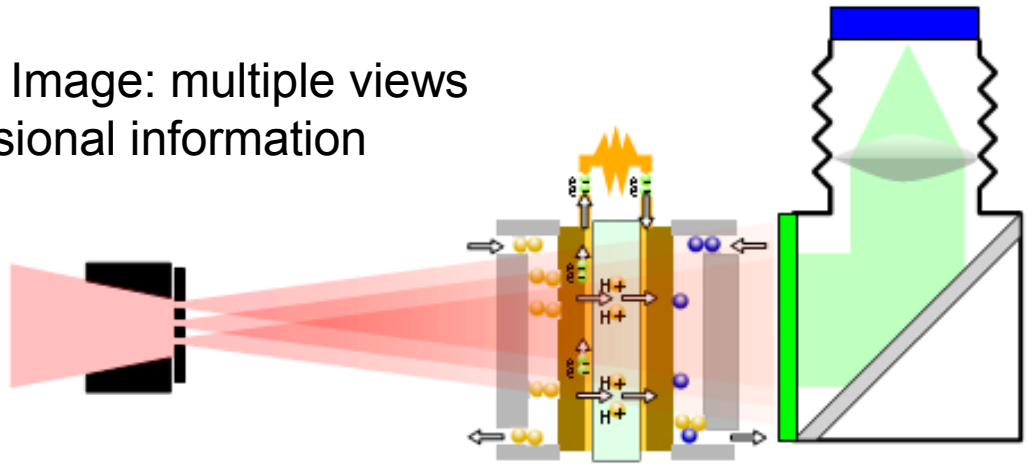
Time resolution:
40 millisecond

Real time 3-D Imaging ?

Monoscopic Image: Single pinhole gives 2 dimensional information only



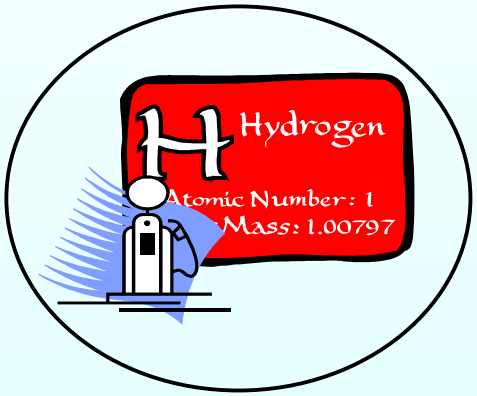
Stereoscopic Image: multiple views give 3 dimensional information

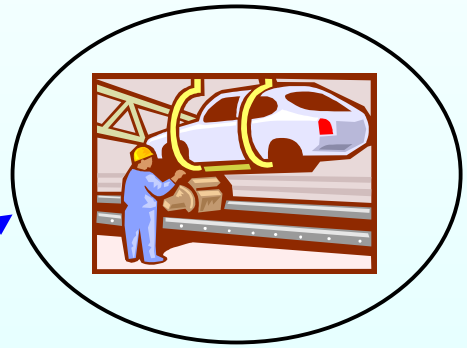


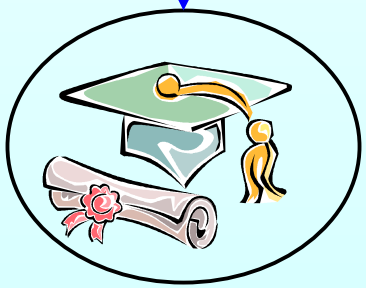
Real time 3 dimensional imaging of membrane would be possible!

Interactions/ technology Transfer

Linking Our Efforts





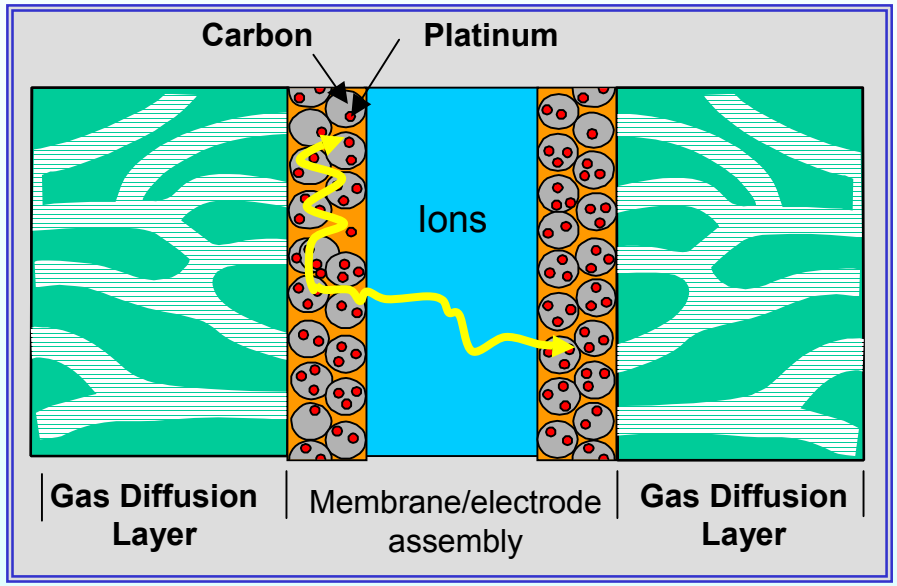


Fuel cell and component manufacturers *

Automotive companies *

- MIT
- Univ. of Miami

Plans and Future Milestones



	Length	Time	
Materials	*0.1 – 10 nm*	*10^{-12} – 10^{-8} s*	Neutron Scattering
Morphology	*0.1 – 10 μm*	*➢1000 s*	Neutron imaging
Water transport	*5 - 100 μm*	*0.1 – 100 s*	Neutron Imaging

Future Milestones

2003-2006

- Extend current measurements of single cells to real world multi-stack cells
- Extend measurements to MEA specific water transport, morphology and structural durability
- Extend measurements to hydrogen storage materials
- Improve spatial and temporal resolutions to near or better than 10 micro-meters and a few tens of milliseconds respectively
- Explore possibilities of near real time 3-D imaging capability using a secondary beam line
- Transfer technologies to industry as they evolve